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Coupled climate network analysis of multidecadal dynamics in the Arctic

M. Wiedermann (1,2), J.F. Donges (1,2), J. Heitzig (1), J. Kurths (1,2)

(1) Potsdam Institute for Climate Impact Research, Transdisciplinary concepts and methods, Potsdam, Germany (donges@pik-potsdam.de), (2) Department of Physics, Humboldt University, Berlin, Germany

Climate network analysis provides a powerful tool for investigating the correlation structure of the dynamical system Earth. Elements of time series analysis and the theory of complex networks are combined to give new insights into the dynamics of the climate system by delivering a spatially resolved image of the underlying correlation structure from which the network is constructed.

Recent results have indicated a possible correlation between the Atlantic Multidecadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO) with a time lag of 15 to 30 years. However, identifying the involved physical mechanisms remains an open problem of ocean science and atmospheric research. We perform a climate network analysis aiming at assessing the importance of the Arctic for this connection between North Atlantic and North Pacific. As storm tracks were suggested to play a role and the large delay between AMO and PDO points to oceanic processes at work, we focus on analyzing the coupling structure between oceanic sea surface temperature (SST) and atmospheric sea level pressure (SAP) as well as geopotential height (GPH) fields. We employ the recently developed theory of interacting networks, with the corresponding statistical cross-network measures, that enables us to study the properties of a coupled climate network that divides into several subnetworks representing horizontal fields of different observables.

As the analysis is performed in a region close to the north pole one has to bear in mind that climatological datasets are often arranged on a rectangular grid such that the density of nodes increases rapidly towards the poles. To correct for the distortions in our results resulting from this inhomogenous node density, we refine the cross-network measures in a way that enables us to assign every node with an individual weight according to the area that the node represents on the Earth's surface. This method has already been applied to the standard set of measures from complex network theory yielding "node splitting invariant (n.s.i.) network measures". The proposed weighted n.s.i. cross-network measures are readily applicable to general geoscientific problems involving networks with differently sized nodes and a given partition into subnetworks or communities.

Our application consists of two parts: In the first part we perform a coupled climate network analysis in order to investigate the interaction between the SST and the SLP field that highlights two regions, one in the Atlantic and one in the Pacific, where SLP shows high coupling with SST. Starting from this we perform a more detailed analysis of coupled climate networks consisting of the SST field and isobaric layers of GPH at different altitudes, respectively. Our results show a strong coupling of the 200 mbar height level of GPH with the sea surface temperature by means of the n.s.i.-cross degree. Furthermore the n.s.i.-cross betweenness centrality points out interesting structures in the vertical direction. These results give first hints at the complex interplay between oceanic and atmospheric processes involved in Arctic climate dynamics.